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Technical Report ARAEW-TR-06002

60mm M225 FATIGUE TEST AND BURST TEST

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August 2005

ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
Armaments Engineering & Technology Center
Weapon Systems & Technology

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
16-08-2005

2. REPORT TYPE
TECHNICAL

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
60mm M225 FATIGUE TEST AND BURST TEST

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Philip C. Wheeler, Dave Haverly, Walt Peretti, Ken Olsen

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army ARDEC
Benet Laboratories, RDAR-WSB
Watervliet, NY 12189-4000

8. PERFORMING ORGANIZATION REPORT NUMBER
ARAEW-TR-06002

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army ARDEC
Benet Laboratories, RDAR-WSB
Watervliet, NY 12189-4000

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The tube fatigue lab was asked to fatigue test four, 60mm M225 mortar tubes, by applying up to 30,000 cycles to each tube. The purpose was to prove that a 60mm M225 mortar tube was safe to fire should the bore diameter reach 2.421 inches. The current bore diameter limit is 2.411 inches. Laboratory fatigue and burst tests were also used to verify Finite Element Analysis. Each tube was tested at a pressure of 10,080 psi at ambient temperature and the test was halted when the tubes reached 30,000 laboratory cycles. Subsequent to fatigue testing, each tube was pressurized until the tube burst. This report describes the equipment and the methodologies that were used for testing the four M225 60mm mortar tubes and the results of the fatigue test and burst tests.

15. SUBJECT TERMS
60mm Mortar; Burst test; Final Safe Life; M225; Condemnation criteria; Safe Service Life

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**	U	21	Phil Wheeler
U/U	U	U			**19b. TELEPONE NUMBER (*Include area code*)** 518-266-4971

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ABSTRACT

The tube fatigue lab was asked to fatigue test four, 60mm M225 mortar tubes, by applying up to 30,000 cycles to each tube. The purpose was to prove that a 60mm M225 mortar tube was safe to fire should the bore diameter reach 2.421 inches. The current bore diameter limit is 2.411 inches. Laboratory fatigue and burst tests were also used to verify Finite Element Analysis. Each tube was tested at a pressure of 10,080 psi at ambient temperature and the test was halted when the tubes reached 30,000 laboratory cycles. Subsequent to fatigue testing, each tube was pressurized until the tube burst.

This report describes the equipment and the methodologies that were used for testing the four M225 60mm mortar tubes and the results of the fatigue test and burst tests.

INTRODUCTION

The tube fatigue laboratory, located at Benet Laboratories, has the responsibility for determining the safe fatigue life of cannons. It has been proven by past experiments that one lab cycle, using hydraulic oil as a pressure medium, equals one live firing of the cannon.

The tube fatigue lab was asked to fatigue test four, 60mm M225 mortar tubes, by applying up to 30,000 cycles to each tube. The purpose was to prove that a 60mm M225 mortar tube was safe to fire should the bore diameter reach 2.421 inches. The current bore diameter limit is 2.411 inches. Laboratory fatigue and burst tests were also used to verify Finite Element Analysis. Each tube was tested at a pressure of 10,080 psi at ambient temperature and the test was halted when the tubes reached 30,000 laboratory cycles. Subsequent to fatigue testing, each tube was pressurized until the tube burst.

This report describes the equipment and the methodologies that were used for testing the four 60mm M225 mortar tubes and the results of the fatigue test and burst tests.

BACKGROUND

Typically, the tube fatigue laboratory tests one component at a time. Since each mortar tube was to be tested to 30,000 cycles, a total of 120,000 cycles would have to be applied by the test equipment to be able to test all four mortar tubes. It would take roughly 15 days of cycle time to generate the 30,000 cycles. This would equate to 60 days of testing to test all four tubes. Due to the large number of cycles that would be needed to test all four mortar tubes, the tube fatigue laboratory recommended testing all four mortar tubes at one time using equipment that was originally designed to test only one 120mm cannon at a time.

This resulted in a substantial cost and time savings by applying only 30,000 cycles to all four tubes at one time rather then applying 120,000 cycles, in total, had each mortar tube been tested individually. The resultant time savings was estimated to be 45 days. Following the lab simulated firing test, each tube was sequentially burst to provide data which could be used to validate engineering models for mortar tubes.

TEST PROCEDURE AND EQUIPMENT

All four of the M225 60mm mortar tubes were tested simultaneously to a target pressure of 10,080 psi. The actual range in pressures achieved by the equipment was between 10,050 psi and 10,107 psi. Due to the time that is required to generate the pressure when using a high pressure intensifier, the cycle rate was 4.5 cycles per minute (all tests in the tube fatigue laboratory use hydraulic intensifiers to generate the high test pressures).

Since the pressure inside the mortar tube drops off as the projectile travels towards the muzzle, testing the whole tube at the chamber pressure of 10,080 psi is not realistic because the muzzle would then be tested at a much higher pressure then it was designed for or would normally experience. For this reason, a shorter region of a tube is typically tested so that a realistic pressure will be applied to the corresponding region of the tube. The objective is to test the most critical areas of the tube, in this case the region of the tube which holds 10,080 psi. For the 60mm mortar this region is at the back end of the tube near the base cap. To determine the length of this region, a pressure-travel curve for the 60mm mortar tube was used. Based on the pressure-travel curve, a tube length of 12 inches, measured from the firing pin hole, was determined to be the appropriate length of tube for the given maximum pressure of 10,080 psi. The muzzle section of each tube was cut off and the remaining 12 inches, including the base cap, was used for testing.

Prior to tube fatigue testing, two of the mortar tubes, S/N 210 and S/N 491, had the inside diameter of the breech end bored out to a larger diameter. Afterwards an additional 435 rounds were fired from each of these tubes at Aberdeen Proving Ground to verify the safety of the oversized tubes. These tests include Extreme Pressure, Extreme Temperature (Hot), Extreme Temperature (Cold) and Reliability. The remaining two tubes, S/N 397 and S/N 1066 were not bored out and exhibited natural wear.

The I.D. of the bore of each tube was measured and documented before lab simulated firing test was performed (see table 1). The I.D. was measured at a location 12 inches from the base end of the mortar tube. This is the location where the cut was made to separate the muzzle end of the mortar tube from the breech section that was to be tested. The inside diameter at the point

12 inches from the base end of the mortar tube is represented in Table 1 as I.D. #1. The inside diameter was also measured at a location that was 9 inches from the base end of the mortar tube, I.D. #2 and 5 inches from the base end of the mortar tube, I.D. #3. The column labeled I.D. #4 shows the maximum bore diameters that were measured. The table shows the results for all four locations on all four mortar tubes. For comparison, the bore diameter of a new mortar tube is 2.392 inches as indicated on the production drawing and the condemnation criteria for a 60mm mortar tube is 2.411 inches. The proposed new condemnation criteria will be 2.421 inches.

Pressure was monitored and recorded throughout the test. In addition to measuring pressure, strain measurements were recorded at the base cap of each mortar tube. The purpose for recording strain was to see if any fatigue crack or dilation was occurring. No residual strain was observed during the 30,000 cycles and no permanent dilation was observed when the test was completed.

All four tubes were removed and inspected when the test was complete. All four tubes exhibited no change in I.D. and no sign of cracking was observed. The strain readings also showed no sign of permanent deformation.

After inspection, all four tubes were individually burst. The theoretical yield pressure was approximately 21,000 psi. The actual bust pressure observed for each tube is given table 2.

Each tube exhibited a fracture that is consistent with a ductile material. The fracture occurred at the extreme end of the tube (furthest from the base cap). On each tube, the failed area was bulged outwards and had a fracture that was between two and four inches in length. No shrapnel or other debris was observed during the burst failure. This is indicative of a good quality mortar tube material.

There were no signs of material deficiencies in any of the tubes. All four tubes performed the 30,000 cycle lab simulated firing test successfully with no cracking or any other anomaly that would indicate failure. All four tubes also exhibited a failure mode during the burst test that would be expected.

The following is a description of the photos and figures in this report. Figure 1 depicts a 3-D representation of the mortar tube test assembly. The assembly consists of a support column (purple column at the bottom of the figure). This column supports the 60mm mortar tube and related hardware. The end plug shaded in green retains high pressure seals which hold the hydraulic pressure. The grey shaded material is the 60mm mortar tube and base cap. A ball bearing and pin (shaded silver) is inserted into the firing pin hole and is used to hold back the internal hydraulic pressure of the mortar tube during testing. The support cap (shaded in green) has a socket machined into it to support the load of the mortar tube. The orange shaded pin is used to lock the pin and ball bearing into place and to apply a compression load to the ball bearing. Figure 2 show the actual hardware that was just described. On the right side of this graphic is a cylinder and a ram. This figure depicts a M256 chamber section of a cannon tube and the hydraulic ram that is part of the 4.5 Million pound press that was used to generated the test pressure. The M256 chamber was used as a manifold to distribute the test pressure to all four mortar tubes simultaneously. In this schematic, the ram would be pushed into the M256 chamber and would compress hydraulic fluid within the chamber. The fluid would then flow from the manifold (M256 chamber), travel through four high pressure feed lines and enter the base of the four 60mm mortar tubes. Figure 3 is a photograph of the control console for the test cell. This is a closed loop computer control system where load and ram stroke can be monitored and adjusted by software to give repeatability during testing. Figure 4 shows the M256 chamber section in the 4.5 Million pound press with the four 60mm mortar tubes mounted on top of support columns. Figure 5 is a close up view of the 60mm mortar tubes that are mounted on top of the support columns with the M256 chamber section in the center. The inlet hole in the base of one of the 60mm mortar tube assemblies can be seen in this photograph. Figure 6 shows the test rig with all the high pressure lines feeding from the M256 chamber. The base cap of each 60mm mortar tube had a single strain gauge applied to it as shown in figure 7. The gauge was applied so that measurements of strain on the base cap during the test could be observed. The strain value was used to determine if permanent strain was forming under the base cap during the test. When the 10,080 psi test was complete, each of the mortar tubes were burst. Figure 8 shows the result of the burst test on one of the mortar tubes. Figure 9 – 15 show the results of the burst test on all four 60mm mortar tubes.

RESULTS

The outcome of this test showed that 60mm mortar tubes could support up to 30,000 simulated fatigue cycles when the bore diameter reached the proposed 2.421 inch condemnation criteria. All four mortar tubes had no sign of fatigue cracks and no permanent strain as a result of the test. The bore diameters were measured before and after the test and the result showed no change in bore diameter. The 30,000 cycles at 10,080 psi resulted in no change in any of the four mortar tubes.

The results for the burst test were consistent, with the fracture occurring at the muzzle end of the tubes and at locations that were consistent with one another. Each tube exhibited a fracture that is consistent with a ductile material. The fracture occurred at the extreme end of the tube (furthest from the base cap). On each tube, the failed area was bulged outwards and had a fracture that was between two and four inches in length. No shrapnel or other debris was observed during the burst failure. This is indicative of a good quality mortar tube material.

Inside Diameter of Mortar Tubes

Tube S/N	I.D #1 12” from base end of tube	I.D #2 9” from base end of tube	I.D #3 5” from base end of tube	I.D. #4 Max bore I.D.
210	2.394”	2.429”	2.4315”	2.432”
397	2.396”	2.397”	2.402”	2.413”
491	2.404”	2.429”	2.4305”	2.431”
1066	2.397”	2.3985”	2.404”	2.416”

Table 1

Burst Pressure

Tube S/N	Burst Pressure
210	25,104 psi
397	25,602 psi
491	26,343 psi
1066	26,900 psi

Table 2

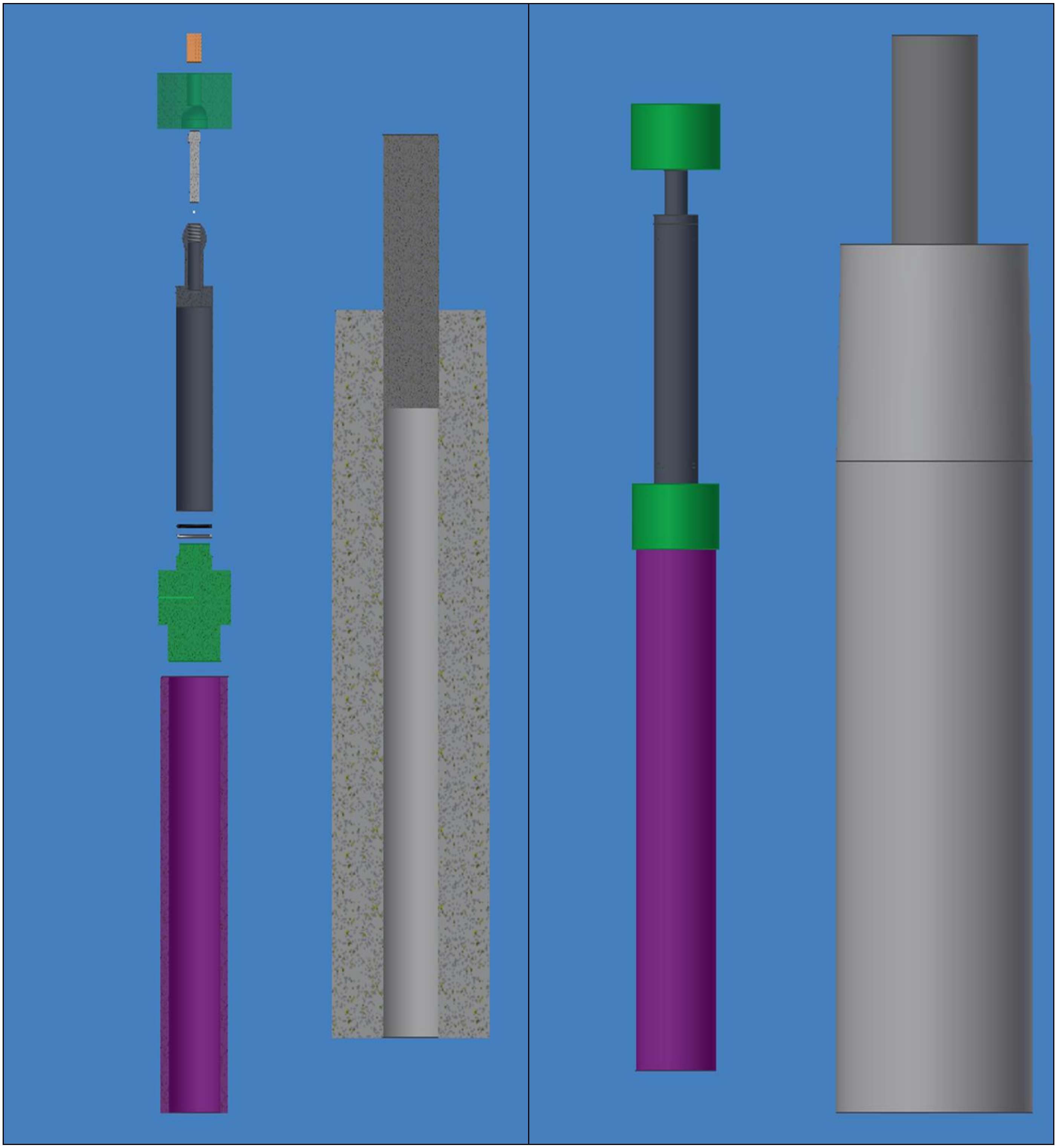


Figure 1

Figure 2

Figure 3

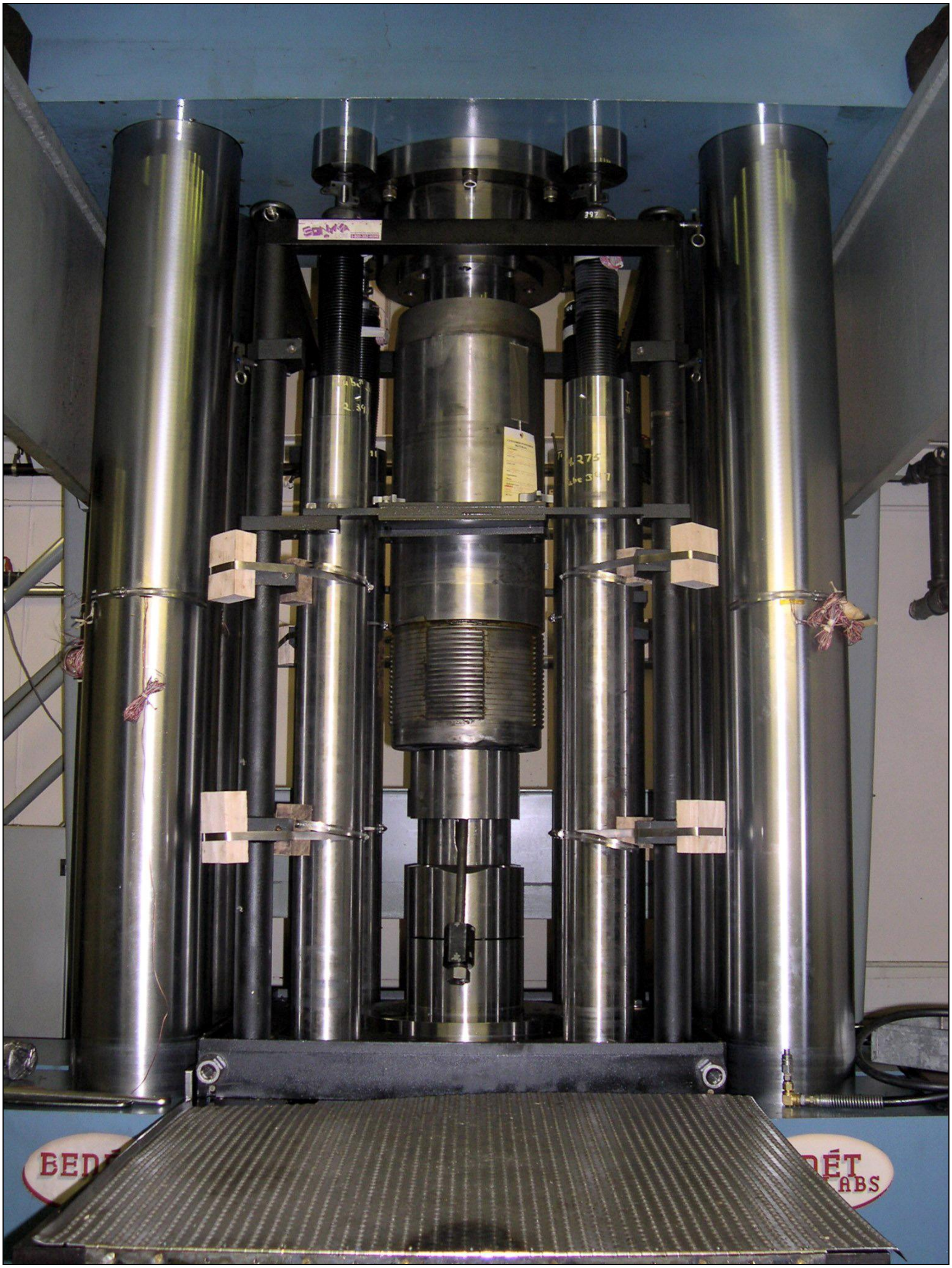


Figure 4

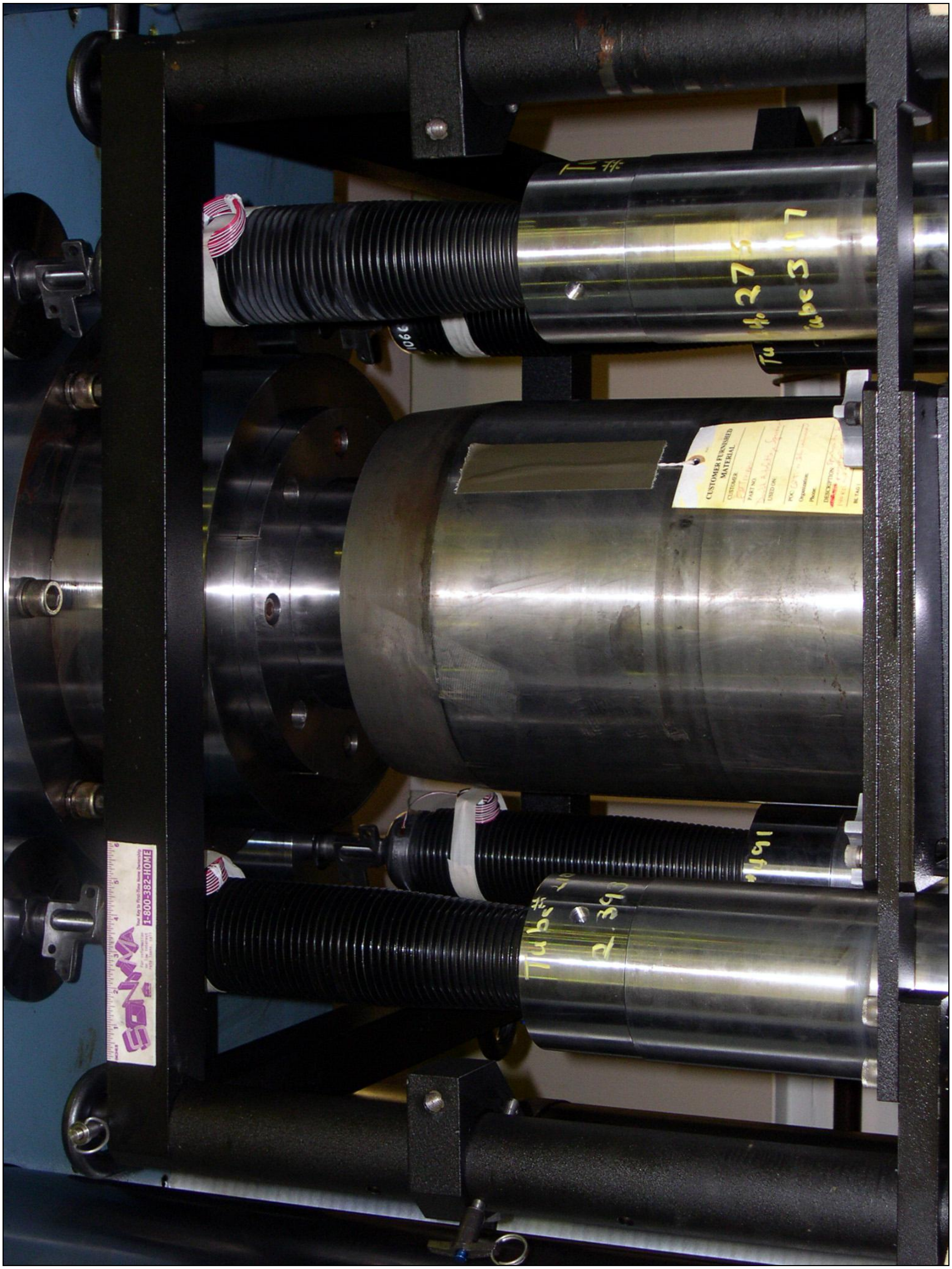


Figure 5

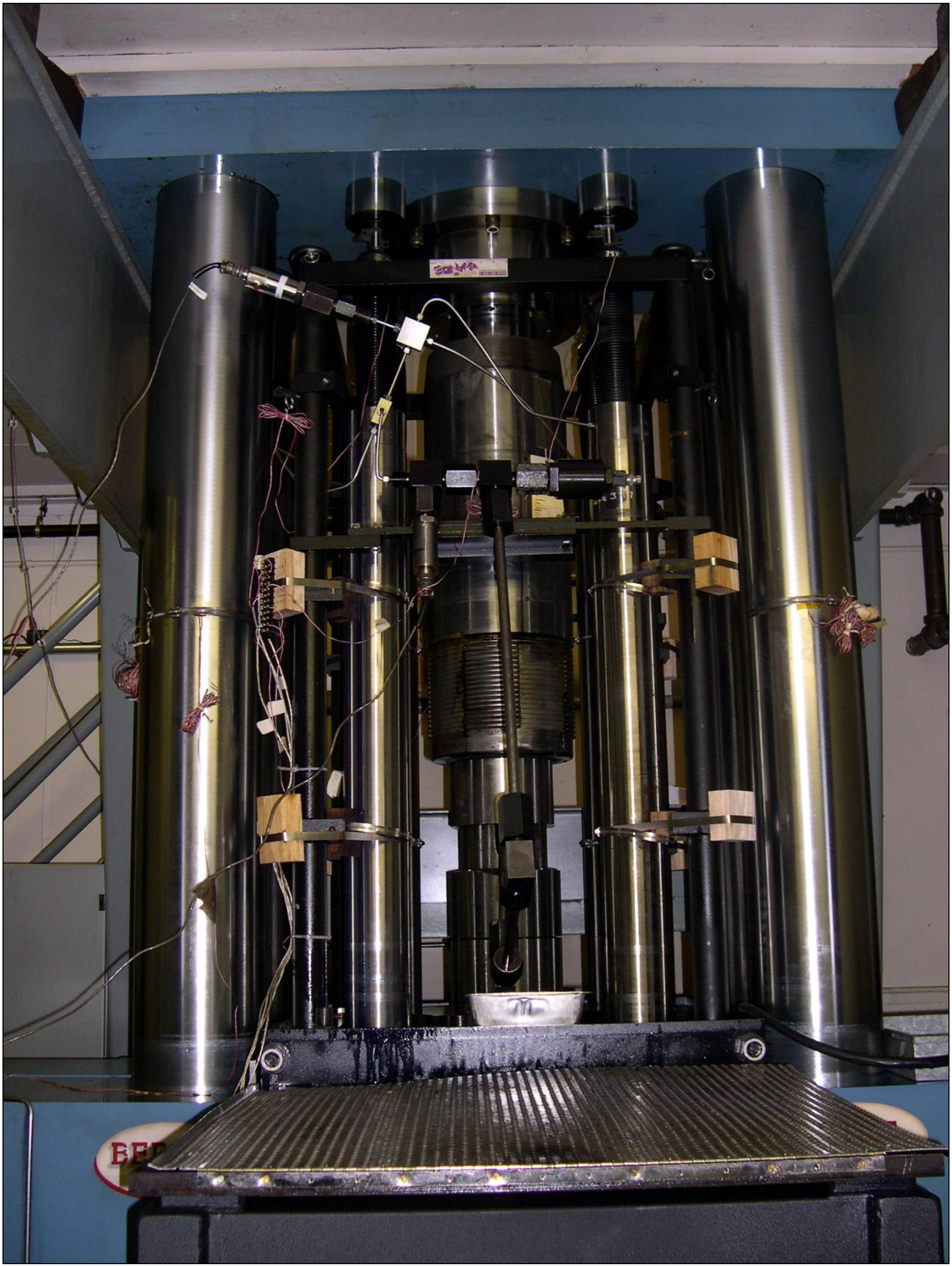


Figure 6

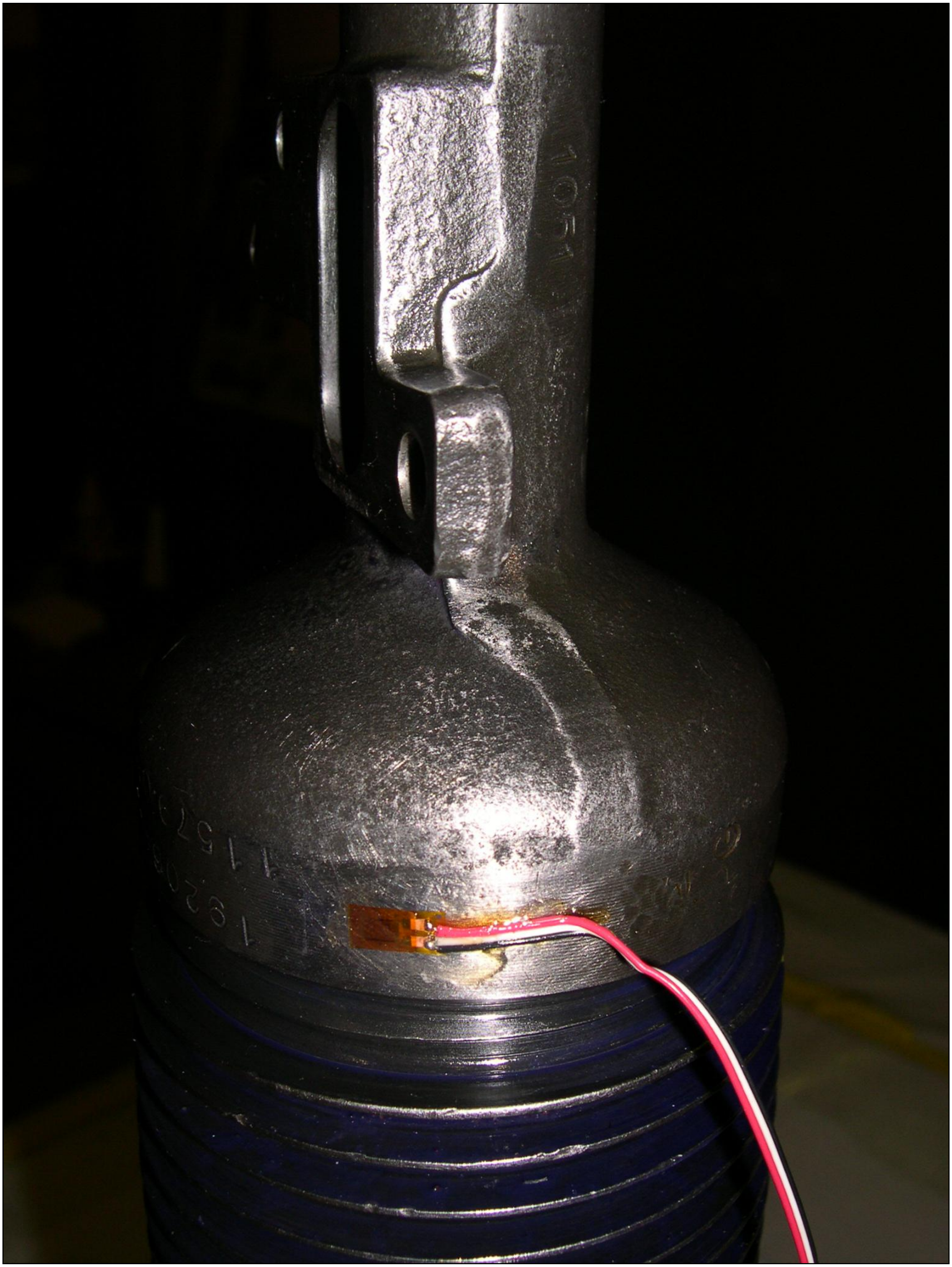
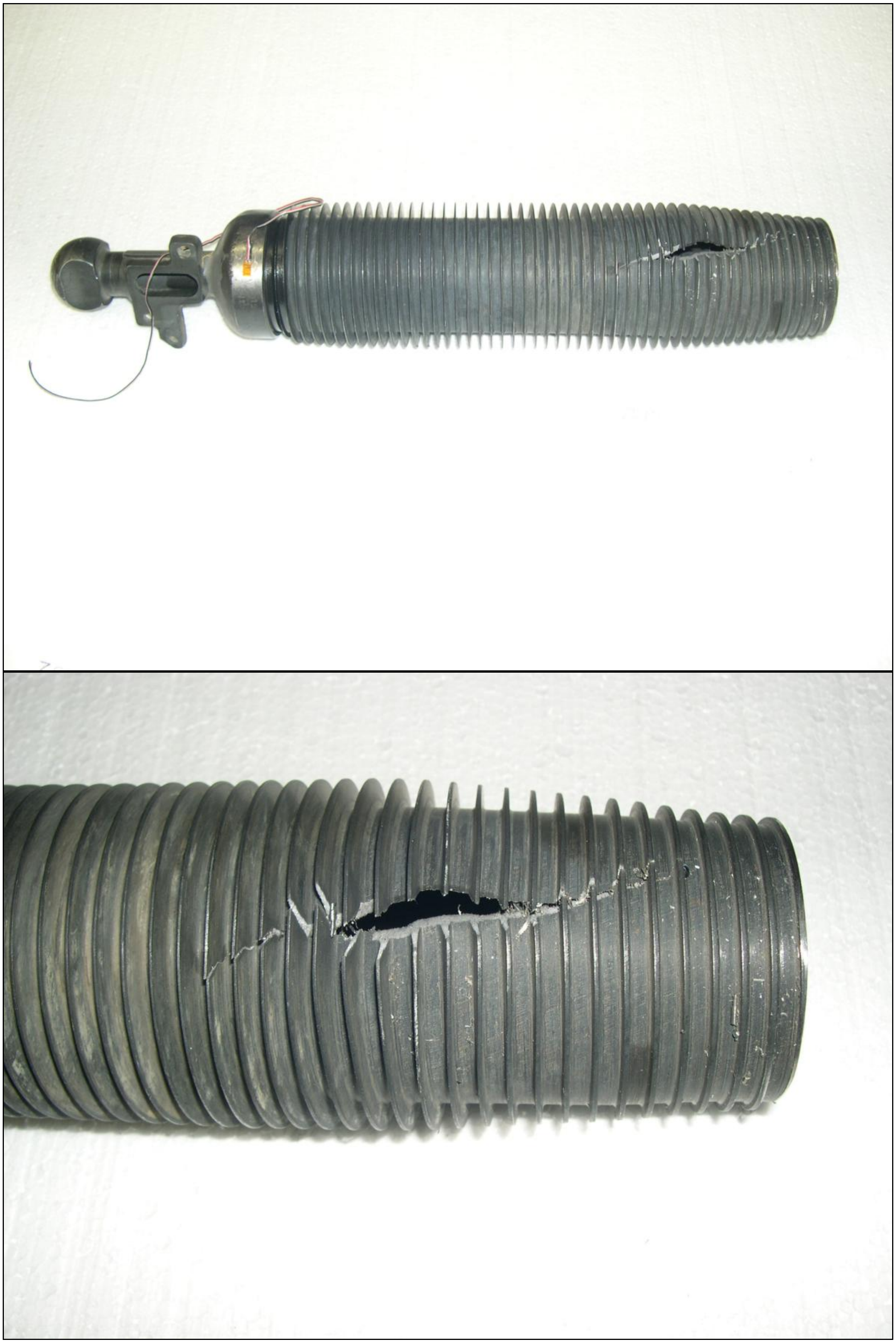


Figure 7

Figure 8



Tube 210
Figure 9

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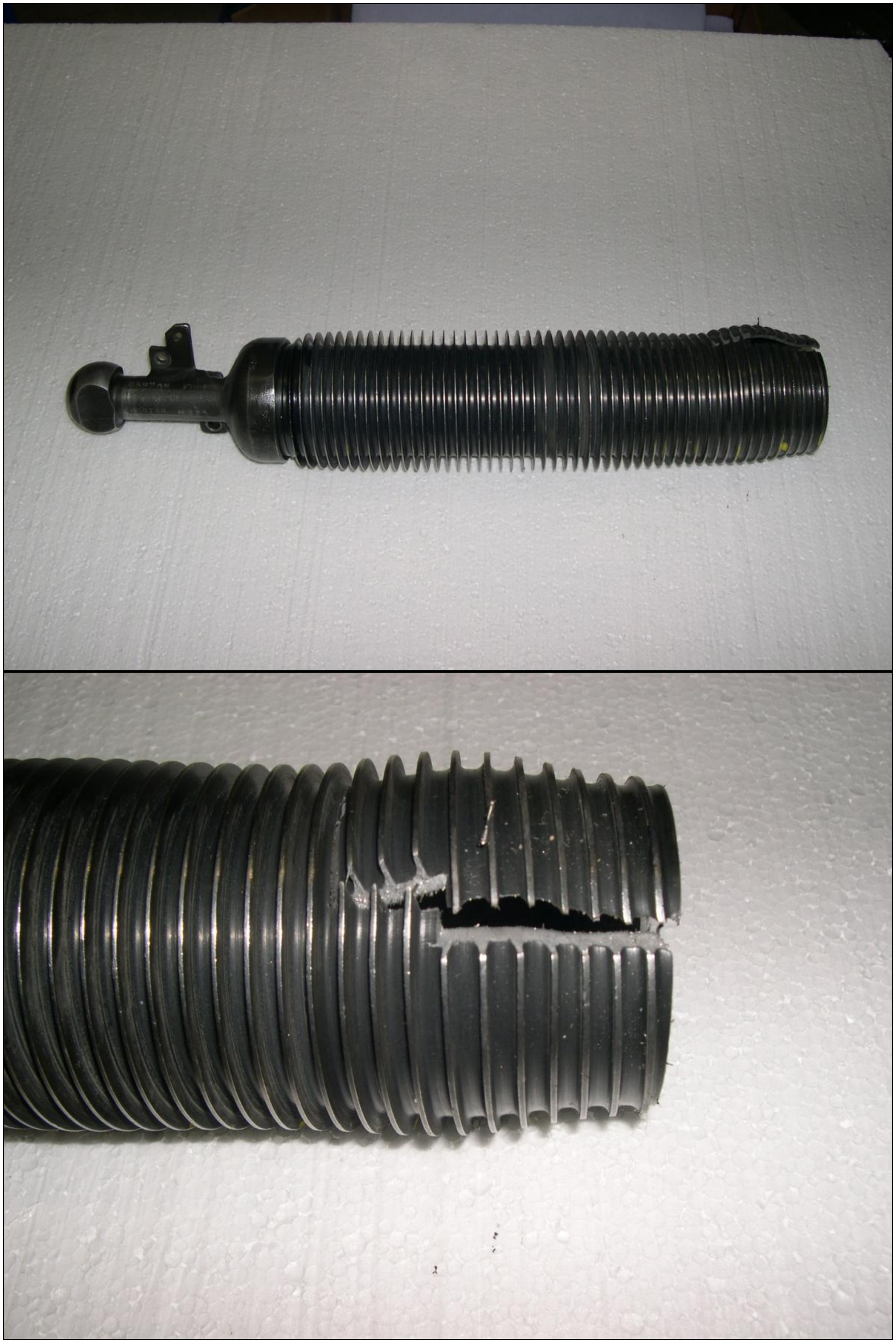
Tube 397
Figure 10

Tube 491
Figure 11



Tube 1066
Figure 12

Tubes 491, 397, 1066, 210, from left to right.
Figure 13

Tubes 491, 397, 1066, 210, from top to bottom (Top Photograph))
Tubes 491, 397, 1066, 210, from left to right (Bottom Photograph)
Figure 14

Tubes 491, 397, 1066, 210, from right to left.
Figure 15